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Dr. LEE, President, in the Chair.

E. D. Johnson, Esq., 9 Wilmington Square;
Rev. R. C. Lumsden, Sheffield;
Basil Woodd Smith, Esq., Hampstead; and
R. C. May, Esq., Great George Street, Westminster,

were balloted for and duly elected Fellows of the Society.

On the Light of the Sun, Moon, Jupiter, and Venus. By G. P. Bond, Director of the Observatory of Harvard College.

In a memoir recently communicated to the American Academy of Arts and Sciences I have given an account of experiments made at the Observatory, during the past year, upon the light of the Sun, Moon, *Jupiter*, and *Venus*. Attention was originally directed to the subject by the remarkable photographic intensity of the light of *Jupiter*, which was first noticed in March, 1851. This property has also been recognised by Mr. De La Rue, who has described his experiments in the *Monthly Notices* of the Royal Astronomical Society, vol. xviii. p. 55. I have found that the reflective capacity of the surface of *Jupiter* for the photographic rays is fourteen times greater than that of the Moon: in other words, out of

an equal quantity of light incident upon each of the two bodies *Jupiter* reflects fourteen times more of the chemical rays than the Moon does. Hence we have,

$$\frac{\text{Photographic albedo of Moon}}{\text{Photographic albedo of Jupiter}} = \frac{1}{14}.$$

I am satisfied that no considerable difference of colour, such as has been supposed by De La Rue, exists in the light of the two bodies — certainly none sufficient to account for their very unequal chemical action. From several trials made for the purpose, it would seem that the reflective capacity of the Moon's surface for the photographic rays is not inferior to that of the objects which give the prevailing tone of light to a landscape-view on the earth. On the other hand, no opaque substance has been found capable of reflecting light sufficient to act upon the plate with the same rapidity as *Jupiter*, when the illumination to which both objects are exposed is reduced to the same intensity.

The experiments, though liable to the uncertainty incident to all photometric measurements, are sufficient to prove an excess of photographic intensity in the light of the planet not susceptible of any ready explanation. They have suggested a series of comparisons of the optical intensity of the light of the bodies in question, which have led to the conclusion that the whiteness (*albedo*) of the surface of *Jupiter* exceeds that of any known opaque substance. Even the dusky belts give more light than an equal area of new-fallen snow would do if exposed to the same intensity of solar illumination. The fact is the more remarkable from the circumstance that occasionally white streaks and minute bright spots have been seen upon its disk much more brilliant than the general surface.

In a question where disturbing influences so easily mislead the judgment, it is desirable to bring together the results of different methods of examination. The following affords, perhaps, the most decisive confirmation of the fact of the superior brilliancy of *Jupiter*. I have found, from my own observations, the photometric proportion

$$\frac{\text{Jupiter at mean opposition}}{\text{Mean full Moon}} = \frac{1}{6430},$$

which is confirmed by the results of Sir J. F. W. Herschel's valuable collection of photometric comparisons made at the Cape of Good Hope, giving

$$\frac{\text{Jupiter at mean opposition}}{\text{Mean full Moon}} = \frac{1}{6620}.$$

This is derived, not from actual comparisons of *Jupiter* and the Moon, but indirectly from the ratio

$$\frac{\alpha \text{ Centauri}}{\text{Mean full Moon}} = \frac{1}{41400},$$

differing from Herschel's result published in his *Outlines of Astronomy*, principally on account of a change introduced into the corrections applied to the light of the several phases of the Moon to reduce them to the full phase, which will be more fully explained presently. For the relation between *α Centauri* and *α Lyræ*, we have

$$\text{Log.} \frac{\alpha \text{ Centauri}}{\alpha \text{ Lyræ}} = 0{\cdot}1200,$$

derived from determinations by Seidel and Herschel. Seidel* has obtained, from a very complete discussion of the subject, the values

$$\text{Log.} \frac{\text{Sun}}{\alpha \text{ Lyræ}} = 10{\cdot}4499 - \text{log. albedo Jupiter},$$

$$\text{Log.} \frac{\text{Jupiter at mean opposition}}{\alpha \text{ Lyræ}} = 0{\cdot}9158.$$

From the above numbers we obtain

$$\text{Albedo of Jupiter} = \frac{532000}{S}$$

where S is the ratio between the light of the Sun and of the mean full Moon. If, now, we substitute in this last result the value

$$S = 550000,$$

which is the mean between the determinations by Bouguer and Wollaston, we find

$$\text{Albedo of Jupiter} = 0{\cdot}967,$$

or more than double that attributed by Lambert to a surface of the finest white lead (cremnitz white), which gave the highest albedo, viz., 0·423, of any substance experimented upon by him.

* Untersuchungen über die Lichtstärke der Planeten *Venus*, *Mars*, *Jupiter* und *Saturn*. 4° Munich, 1859.

The values attributed to S by Bouguer and Wollaston, viz.,

$$S = 300{\cdot}000 \text{ by Bouguer,}$$
$$S = 810{\cdot}072 \text{ by Wollaston,}$$

are certainly very discordant, though not more so, perhaps, than the difficulties attending the subject would lead us to expect. A new determination, which I have made by a method differing from those employed by them, gives

$$S = 470{\cdot}980.$$

I have made use of the Bengola light as an intermediate standard of comparison, the colour of its light agreeing very closely with that of moonlight. The observations upon the intensity of moonlight give

$$\text{Albedo of Moon} = \frac{45{\cdot}193}{S}$$
$$\text{,,} \quad \text{,,} = \frac{1}{12{\cdot}2} \text{ for } S = 550{\cdot}000,$$
$$\text{,,} \quad \text{,,} = \frac{1}{10{\cdot}4} \text{ ,, } S = 470{\cdot}980,$$

for the relative albedos of the Moon and *Jupiter*.

$$\frac{\text{Albedo of Moon}}{\text{Albedo of Jupiter}} = \frac{1}{11{\cdot}47},$$

and, consequently, for *Jupiter* an albedo of very nearly unity, if we take $\frac{1}{11}$ as the albedo of the Moon. Thus all the data indicate a remarkable excess of brilliancy in the light of *Jupiter*.

For the relative albedos of *Venus* and *Jupiter*, I have found the proportion $\frac{1}{1{\cdot}10}$. Seidel gives $\frac{1}{1{\cdot}044}$ for the same ratio. I am inclined to think, however, that the albedo of *Venus* is, in both instances, estimated too high, since it depends mainly upon observations made near the epoch of greatest brilliancy, or between that point and the inferior conjunction, where the illuminated phase occupies but a small part of the disk. The line of incidence and reflection thus approaches the direction of a tangent to the surface; and, as a necessary consequence, the tendency to regular reflection in an opaque surface so presented will have the effect of increasing the quantity of light received from the crescent phases, especially as the planet approaches inferior conjunction.

It is not possible to estimate the amount of light regularly reflected; but there can be no doubt that Lambert's phase-formula, which has been employed in the reductions, will give, on this account, a sensibly higher albedo from observations at the narrow crescents than would be obtained from other phases.* Seidel's observations contain a confirmation of this inference.

In comparing the light of the Moon with the light emitted through a small aperture in a screen placed in front of the flame of a Carcel lamp, arranged with a view to secure a constant standard of illumination, I have obtained the following values of the logarithms of the quantity of light received from its various phases: v represents the angle of elongation of the Moon from the Sun, and H_0 the relative quantity of moon-light from the corresponding phase, taking the light of the mean full Moon as the unit.

$v =$	0°	Log. $H_0 = -\infty$
	20	,, 7·224
	40	,, 8·049
	60	,, 8·574
	80	,, 8·974
	100	,, 9·291
	120	,, 9·551
	140	,, 9·763
	160	,, 9·931
	180	,, = 0·000

The observations have been freed from the effect of atmospheric extinction, and reduced to the mean distance of the Moon from the Earth and Sun.

Herschel's photometric observations made at the Cape of Good Hope upon the light of the Moon and of various fixed stars have furnished, after reduction, the following comparisons with value of log. H_0 taken from the above table —

	Log. H_0.	Cape Obs.	Diff.	Wt.
$v =$ 102°·2	9·324	9·368	−0·004	7
121·7	9·574	9·560	+0·014	8
131·3	9·681	9·711	+0·030	9
135·7	9·724	9·725	−0·001	9

* It is well known that *Venus* is visible in the day time to the naked eye, at near the time of its greatest brightness. I have often seen *Jupiter* with the naked eye while the sun was high above the horizon and shining clearly; and, on one occasion, *Sirius*. From the readiness with which the latter could be discerned, in a position where much of its light must have been lost by atmospheric extinction, I should think it possible to see *α Lyræ* also under favourable circumstances.

	Log. H_0.	Cape Obs.	Diff.	Wt.
$v = 143°7$	9·805	9·778	+0·027	10
158·7	9·920	9·868	+0·052	13
167·0	9·964	9·991	−0·027	6
179·3	0·000	0·157	−0·157	2

With the exception of the last difference, depending upon an isolated observation made under unfavourable circumstances, there is a good agreement between the two series. The present reduction of the *Cape Observations* has been made without regard to Herschel's hypothesis respecting the impression made by the light of the stars upon the eye, as influenced by a change in the illumination of the background of the sky by varying amounts of moonlight, viz., that "the effective impression of a star on the retina is inversely as the square of the illumination of the ground of the sky on which it is seen projected." *

From the manner in which our values of log. H_0 have been obtained, they could not have been affected by this condition; and their accordance with the *Cape Observations*, uncorrected by the hypothesis, shows very clearly that the latter is not necessary to satisfy the observations. And yet it is remarkable that Herschel should have been able, by means of it, to represent completely a large series of observations otherwise wholly discordant. From a full investigation of the subject, the details of which are presented in the memoir, it appears that the true explanation of the discrepancies noticed by Herschel is to be found in the anomalous manner in which the Moon reflects light to the Earth from its different phases, in consequence of which the quantity of moonlight increases much more rapidly towards full-moon, compared with the phases on either side of it, than can be accounted for by the formulæ of Lambert or of Euler—so much so that, taking the full-moon as a standard, even Lambert's, which accords best with observation, makes the observed light at quadrature from two to three times fainter than is indicated by the theory.

Herschel's formula for the relative enfeeblement of the light of the stars, while it affords a very precise representation between quadratures and full-moon, if interpreted as a consequence of an actual variation of the amount of moonlight, is perfectly consistent with the results of my own investigation for the limits including the observations which have been discussed by him.

The following are the results of a comparison of the logarithms of the observed amounts of mean moonlight at different angles of elongation; v, the unit, being the amount from the

* *Results of Astronomical Observations made at the Cape of Good Hope*, p. 356.

mean full-moon for which $v_0 = 180°$, with the logarithms computed from the formulæ of Lambert and Euler, and from an empirical formula, in which the light is assumed to vary as $\sin^6 . \frac{1}{2} v$, which differs scarcely sensibly in its results from Herschel's formula under the above construction of its significance. It will be seen that the latter accords well with observation up to about $v = 90°$, and suddenly diverges from a correct representation between new and half-moon, phases which were not included among the *Cape Observations*.

	Obs'd. Moonlight.	Lambert. Euler and Herschel.		
	Log. H_0.	Log. $\frac{\sin v - v \cos v}{\sin v_0 - v_0 \cos v_0}$	Log. $\sin^2 \frac{1}{2} v$.	Log. $\sin^6 \frac{1}{2} v$.
$v =$ 0	$-\infty$	$-\infty$	$-\infty$	$-\infty$
20	7·224	7·653	8·479	5·438
40	8·049	8·536	9·068	7·204
60	8·574	9·037	9·398	8·194
80	8·974	9·374	9·616	8·848
100	9·291	9·613	9·768	9·305
120	9·551	9·785	9·875	9·625
140	9·769	9·903	9·946	9·838
160	9·931	9·975	9·987	9·960
180	0·000	0·000	0·000	0·000

On the Spiral Structure of the Great Nebula of Orion. By G. P. Bond, Esq., Director of the Observatory of Harvard College.

A disposition in the light of this nebula to radiate outwards and in a southerly direction from the neighbourhood of the *trapezium*, is noticed in my father's memoir, published in 1848, in which are named, as particular localities, Herschel's subnebulous region and the preceding side of the *Regio Huygeniana*. This peculiarity has since attracted attention on many occasions; but it is only recently that it has been subjected to a minute and systematic examination, the results of which I propose now to communicate.

In the season of 1857–58 I undertook the formation of a catalogue of the stars comprised within a square of 40′ having *θ Orionis* as its centre. One hundred and twenty-one of the brighter stars were selected, and their positions determined, to serve as points of reference for filling in the remainder, which were mostly too faint for observation under a strong illumination of the micrometer wires. This was completed in 1858. The order of magnitude of the stars was subsequently made

the subject of careful study by the method of sequences described by Sir John Herschel in the "Results of Astronomical Observations made at the Cape of Good Hope." The whole number of stars included up to the end of the season, 1857–58, was two hundred and sixty-two; but it must be remembered that innumerable fainter stars have been omitted, on account of the difficulty of observation, and many of them appearing only on occasions of the finest definition.

In the following year, 1858–59, the area above indicated was divided into four charts, on which the outlines of the nebulosity were traced in chalk and white water-colour, laid on a dark ground. These were next combined in a single drawing, which was subsequently compared with the nebula, and corrected. The particular feature, which it is now proposed to describe, did not, however, present itself in its full force until the present year. During the months of December, January, February, and March last, favourable opportunities were taken to review the whole region, with particular reference to the arrangement of the nebulosity in long wisps, alternating with darker spaces sweeping outwards from the vicinity of the *trapezium*. A careful scrutiny of the intermediate dark channels was of considerable assistance in tracing the fainter convolutions.

The form and dispositions of the whirls were thus defined by two independent processes, the nebula being first sketched as a bright object on a dark ground, and again, its darker openings and channels as dark objects on a bright ground.

The quarter designated in Herschel's chart* as the *Regio Godiniana* was first explored. The nebulosity was here resolved into an assemblage of three or four long wisps, interlaced with each other, or crossed by off-sets, which were ultimately traced from a point near the northern margin of the *Sinus Magnus*, over the whole length of the *Regio Picardiana* and the *Regio Godiniana*, forming a sweep of 120°. After passing the well-defined northern boundary of the last-named region, and beyond Herschel's stars *o* and ξ, these wreaths bend rather suddenly, and tend towards the south preceding direction. Indications of their presence in this quarter are imperfectly suggested in Lassell's and in Sir J. Herschel's latest drawing. From this point feeble traces exist for 10′ or 15′ in a south preceding direction. Their course over the *R. Picardiana* gives a decidedly reticulated aspect to the whole region; but, though bright, they are here so closely intertwined and connected by off-sets, that it is a matter of no little difficulty to gain a clear comprehension of their proper relations. The complexity of the details is further increased by several off-shoots from this quarter, which cross over into the adjacent *R. Derhamiana;* still the general effect is easily recognised.

* *Mem. Ast. Soc.* vol. ii.

From the southern corner of the *Regio Picardiana*, and from those parts of *R. Derhamiana* and *R. Huygeniana*, which lie near the *trapezium*, on its north preceding and preceding sides, a number of narrow and bright branches diverge, their extremities tending also to the south preceding direction. Some of these cross the *R. Gentiliana*, and seem to merge together, forming a nebulous mass, which can be followed through an arc of 10′ or 15′. Others, which are less curved, originate near the *Sinus Gentilii;* these are narrow and somewhat tortuous.

It is to be noticed that the initial direction of the wreaths (*Nebelstreifen*) changes continuously from an angle of position of 330°, on the northern margin of the *Sinus Magnus*, to one of 220°, or less, at the *S. Gentilii*, and the sweep of the curve correspondingly diminishes, so that throughout the whole nebulous region preceding the sharply-defined apex of the *R. Huygeniana*, the extremities of the filaments have a pretty uniform tendency in the angle of position, 220°. As soon, however, as we pass to the fields on the following side of the apex, a change is immediately apparent; the ultimate direction being about in the angle 160°. The principal group of wisps results from the resolution of the *R. Messeniana*, and the region between the *trapezium* and the *Proboscis Minor*, including both these features, into four or five distinct wreaths, having a common initial direction in the angle of position 110°. The very bright nebulosity lying between the *S. Gentilii*, the *trapezium*, and the *R. Subnebulosa*, cannot be resolved into a regular structure, but three or four condensed spots, constituting the most brilliant part of the nebula, close on the south preceding side of the *trapezium*, are plainly distinguished as tufts or curled off-sets from a prominent wisp of light, which extends from its origin near the *trapezium* across the *R. Gentiliana*.

The general aspect of the greater part of the nebula is, therefore, that of an assemblage of curved wisps of luminous matter, which, branching outward from a common origin in the bright masses in the vicinity of the *trapezium*, sweep towards a southerly direction, on either side of an axis, passing through the apex of the *Regio Huygeniana*, nearly in the angle of position 180°. About twenty of these convolutions have been distinctly traced, while others, giving a like impression, are too faint or too intricate to be subjected to precise description. It may, in fact, be properly classed among the "spiral nebulæ," under the definition given by their first discoverer, Lord Rosse; including in the term all objects in which a curvilinear arrangement, not consisting of regular re-entering curves, may be detected.

That the existence of this feature in the great nebula of *Orion* should have hitherto escaped notice, after the many careful scrutinies to which it has been subjected with the help of the largest instruments and the most skilful observers, may

seem scarcely credible. A few words of explanation on this point will not, therefore, be amiss. It is to be ascribed partly to the confusing effect produced by the crossing and intersection of the principal striæ and of their off-sets, which the eye cannot unravel without the aid of some clue to their mutual relation and significance, and partly also to the faintness of some of the details, which are, nevertheless, very essential features in a correct apprehension of its structure, supplying, as they do, what would otherwise appear as breaks of continuity, and assisting materially in the recognition of a principle of regularity pervading the whole structure. Until the law of relation and continuity in the several parts of such an object is entertained in the mind, it must remain an incoherent, confused assemblage of material, having no orderly or connected arrangement.

The change from the previous notion of its configuration is not more considerable than that which took place with reference to the celebrated nebula 51 *Messier*, in which the original discovery of the spiral arrangement was made. This object had been subjected to a careful examination and description by both the Herschels; but neither their drawings nor descriptions furnished the slightest intimation of a spiral structure. It deserves particular notice, too, that there was no want of sufficient optical power to exhibit the appearance in question; for the spirality is seen with perfect distinctness in a refractor of 15 inches aperture, and must certainly be within reach of the 20-foot Herschelian reflectors. Nor can it for a moment be thought that the earlier observations and delineations were in any proper sense erroneous. They were simply made at a great disadvantage in the absence of a clear conception of the general plan of structure presented in the object. Some of the details indispensable to its recognition, being only faintly presented, were overlooked, or, appearing by mere suggestions and glimpses of vision, they conveyed an erroneous impression: in this way the mutual relation of the various parts came to be entirely misconceived. The missing links were supplied by the larger optical power of Lord Rosse's telescope, too plainly not to insure notice; and the nebula then presented itself under a totally different aspect. Instances of similar revelations, completely at variance with previous conjectures, have indeed so often occurred in the history of astronomical discovery, that the process ought to be regarded as the ordinary rule rather than as an unusual exception.

There are several other features of minor importance which have engaged attention in the course of this survey of the nebula. One of these is the large number of instances in which collections of nebulous matter are found associated with stars, frequently in the form of little wisps, shooting off in a southerly or south preceding direction. Another is the predominance of small stars in the nebulous regions. Two

remarkable instances occur where there is a deficiency of nebulous matter in close proximity to bright stars, which are yet closely encircled by it. These are the bright groups of the *trapezium*, the central comparative darkness of which has been noticed by many observers, and *ι Orionis*. Lord Rosse's figure of the latter is decisive in this point. These features seem to favour the idea of a physical association of the stars with the nebula. The existence of a spiral arrangement of its component parts falls in with the suggestion of a stellar constitution, since, among the objects exhibiting this peculiarity, are included, not only resolvable nebulæ, but actual star-clusters, such, for instance, as the great cluster in *Hercules*, which has an unquestionable curvilinear sweep in the disposition of its exterior stars.

On the Morning Illumination of the Western Portion of the Mare Humorum. By W. R. Birt, Esq.

In the communication which I had the honour of submitting to the Society at its last meeting, I solicited attention to the appearance of those craters that, standing near the borders of the *Mare Humorum*, had had those portions of their walls broken down that faced the *Mare*. As an admirable opportunity occurred on the evening of April 20th, 1861, of noticing the morning illumination of the western portion of the surface of the *Mare*, which presented some features, perhaps interestingly connected with those that have already claimed attention, some of which appear to be but obscurely indicated in Beer and Mädler's map, I have considered it important to submit to the Society my observations of them as a further contribution to the selenography of this part of the Moon's surface.

At $7^h\ 15^m$ G.M.T., April 20, 1861, the terminator crossed the *Mare*, extending from the western flank of *Gassendi* to the western wall of *Vitello*, the interior of the eastern wall of which was very brilliant, its floor as well as the included mountain being in perfect darkness.

The western flank of *Gassendi* appeared to be very rugged, a portion only of the summit of the south-west wall was seen projecting into the night side of the Moon; this illuminated portion terminated abruptly, the last peak being detached. To this detached peak, which Beer and Mädler mark *θ*, I beg to solicit attention presently.

On the surface of the *Mare* between the line across it, joining the two ringed mountains above named, and its western borders, including the arm on which *Hippalus* stands, occur

some interesting *curved* ridges, the convexities of the curves being directed invariably towards the border of the *Mare*, as if they had resulted from the operation of a force that had so acted as to elevate them in some degree *parallel* with the border, *the least parallelism occurring towards the centre of the Mare*. These ridges are true elevations above the surface, casting well-defined shadows. In describing them for the sake of easy reference, I append to each a Roman numeral.

I. This ridge is at this epoch of illumination nearest the terminator; it takes its rise at its southern extremity from the point of intersection between the eastern wall of the ring of *Vitello* and the western of the large disrupted crater, mentioned in my last communication, and runs with a slight divergence from parallelism with the terminator, for about one-fifth of the breadth of the *Mare*, *i. e.* from *Vitello* to *Gassendi*. At this point, marked ϑ by Beer and Mädler, it abruptly changes its direction, running here towards the north-west, casting a considerable shadow; and, from a later period of the observations, this part would appear to be the western ring of a nearly *obliterated* crater greatly ruined. The ridge terminates *in a point against* a small crater marked D in Beer and Mädler's map. *The crater is perfectly detached from this point, and appears to have been elevated on the southern extremity of a ridge, forming a continuation of the foregoing*, and extending about half-way across the *Mare*. The crater is more elevated than the ridge, and casts a well-defined shadow. I have italicised the position of the crater D, as Beer and Mädler's map exhibits a *continuous* ridge.

II. and III. Westward of I. two ridges take their rise respectively from two mountains north of *Vitello*, marked by Beer and Mädler as two craters E and F, the eastern F being very near the ridge I, and the western E north-west of *Vitello*, and north-east of a small crater on the surface of the *Mare*, just within its south-west mountainous boundary, not given by Beer and Mädler, unless the crater E be it; in which case we have no mountain on the map. These two ridges, the rise of which from the mountains or craters are not given by Beer and Mädler, *converge*, and with more or less sinuosity skirt the ridge I, both receding considerably from it in the neighbourhood of the crater D, well shown by Beer and Mädler, with one between, which was not apparent to me on the evening of the 20th. In this part of their course they form considerable *bends* around the crater D, both apices of the bends being in a line with the crater.* A little to the north

* On consulting Beer and Mädler's map, I find the crater D, the apices of the bends of the ridges, and the partially destroyed crater *Hippalus*, *in the same line*. I shall look, should I have the opportunity on a future occasion, with great interest for an ocular confirmation of this. 1861, May 20, 11 to 12 hours; *Hippalus* is in the same line with the bends and crater D, but not that portion of the wall that appears to have been destroyed.

of these bends, the ridges II. and III. unite, and proceed to a point nearly midway between two small craters that appear to have been elevated at a period posterior to that of the formation of the surface of the *Mare*. Beer and Mädler mark the eastern crater 1, and bring the whole of the united ridges to it. This I failed to see.

Beer and Mädler depict the ridges in this part of the *Mare* as being more numerous than I was able to ascertain. My observations were made without reference to the map. I did not consult it until some days afterwards.

IV. From the westernmost of the two craters just alluded to, a slightly undulating ridge extends to the southern wall of *Gassendi*, and passes into the night side of the Moon as a fine delicate line of light.

As the illumination of the southern wall of *Gassendi* proceeded, the separate peak θ of Beer and Mädler, mentioned above, was seen to occupy a position *slightly within* the general boundary of this portion of the ring of the crater, *as if it had been pushed inwards towards the crater*. This is well depicted by Beer and Mädler. It is at this point that the ridge IV. terminates, apparently resting as a buttress against the dislodged part of the ring, also well shown by Beer and Mädler; the remaining portion of the southern wall of *Gassendi* towards the east attains a much lower altitude, as, during the continuance of the observations, four hours, every part remained in darkness.*

V. and VI. Two somewhat lower ridges extend from the bend of III. to the crater from which IV. takes its rise; one only of these depicted by Beer and Mädler.

The above-described ridges, which were all I was able to see with my instrumental means, are situated on the western part of the *Mare Humorum;* they can hardly, if at all, be regarded as ranges of mountains, but may, I apprehend, be considered as ranges of *low* hills, the wall of the nearly obliterated crater rising to the greatest height. The curve of this wall is not well shown by Beer and Mädler.

Epoch, 1861, April $20^{d}{\cdot}37$; Moon's age, $10{\cdot}57$. Greatest libration, S.E. $+ 2^{d}{\cdot}64$; epoch, April $17^{d}\ 17^{h}\ 19^{m}$. Perigee, $- 3^{d}{\cdot}58$: epoch, April $23^{d}\ 23^{h}$.

* From my observations of May 20, 11 to 12 hours, it would appear that the southern part of the ring is scarcely, if at all, elevated above the surface of the *Mare*.

Phenomena of Jupiter's Satellites observed with the Telescope of the Heliometer, at the Radcliffe Observatory, Oxford. By the Rev. R. Main.

1861, April 17. While engaged in attempting to complete the adjustment of the half-object-glasses of the heliometer, by means of the image of *Jupiter*, I observed that the 1st and 2d Satellites were approaching each other; and it appeared to me that they would pass very nearly, if not exactly, over each other. I, therefore, continued to watch them till the conjunction took place, and was not disappointed, as they came into actual contact, and covered each other so completely, that only one single object with perfect sphericity was visible.

I first used a power of 150, and when they came very near each other, I put on a power of 200; but with neither was the definition very good, on account of the east wind. I had previously made these images, formed by the halves of the object-glass, cover each other at the zero very satisfactorily.

The following is the observation of time of contact:—

The conjunction appeared to be perfect — that is, I could perceive no defect of sphericity at $12^h\ 30^m\ 30^s$ clock time (sidereal.)

I could discern no change up to $12^h\ 38^m$, when I began to perceive that the image was elongating.

At $12^h\ 39^m\ 45^s$, I could perceive that the satellites were separating, though the surfaces were still in contact.

At $12^h\ 41^m\ 45^s$, they had separated by a space equal to the diameter of either, the diameters appearing to be very nearly equal.

Satellite I. was approaching *Jupiter*, and Satellite II. was receding from him on the (apparently) west side.

The clock time was 50^s slow of sidereal time.

1861, April 23. *Eclipse (reappearance) of Jupiter's 3d Satellite.*

The satellite was seen, very faint, at $13^h\ 19^m\ 15^s$ clock time, and took several seconds to acquire its full brightness. The observation very good.

The clock was slow of sidereal time $1^m\ 3^s{\cdot}8$.

Hence Oxford sidereal time of reappearance was $13^h\ 20^m\ 18^s{\cdot}8$, and the mean solar time was $11^h\ 12^m\ 25^s{\cdot}1$.

The Greenwich mean time given in the *Nautical Almanac* is $11^h\ 15^m\ 18^s{\cdot}3$.

April 24. *Eclipse (reappearance) of Jupiter's 2d Satellite.*

The satellite was first seen, exceedingly faint, at $12^h\ 25^m\ 13^s$ clock time, and it did not reach its full brightness for more than a minute.

The clock was slow $1^m\ 5^s{\cdot}0$.

Hence Oxford sidereal time of reappearance was $11^h\ 26^m\ 18^s{\cdot}0$, and the mean solar time was $10^h\ 14^m\ 37^s{\cdot}2$.

The Greenwich mean time given in the *Nautical Almanac* is $10^h\ 20^m\ 18^s{\cdot}9$.

May 6. *Eclipse* (*reappearance*) *of Jupiter's 1st Satellite.*

The satellite was seen as a very minute point, not brighter than the 12th magnitude, at $12^h\ 10^m\ 41^s$ clock time; and I watched it till it seemed to have acquired its full brightness, which was not till $12^h\ 12^m\ 30^s$ (though clouds which partially veiled it after the reappearance for a few seconds at a time may have interfered with my judgment).

The clock was $1^m\ 14^s$ slow.

Hence Oxford sidereal time of reappearance was $12^h\ 13^m\ 44^s$, and the mean solar time was $9^h\ 14^m\ 54^s{\cdot}3$.

The Greenwich mean time given in the *Nautical Almanac* is $9^h\ 18^m\ 20^s{\cdot}9$.

A communication was received from Mr. Thomas Barneby, giving an account of the appearance of *Jupiter* and his satellites, as observed on the night of the 5th April, 1861. The shadow of the third satellite was at first seen in the shape of a broad dark streak, such as the cone of the shadow would represent in a slanting direction; but it shortly afterwards appeared as a circular spot, perfectly dark, and much larger than the shadow (which was visible at the same time) of the third satellite. The phenomena were illustrated by a sketch.

Results of Meridional Observations of Small Planets; and of the Observations of Phenomena; made at the Royal Observatory, Greenwich, during the month of April, 1861.

(*Communicated by the Astronomer Royal.*)

Iris (7).

Mean So'ar Time of Observation.		R.A. from Observation.	N.P.D. from Observation.
	h m s	h m s	° ′ ″
1861, April 16	13 56 8·0	15 36 51·95	113 45 15·68
24	13 18 25·5	15 30 35·66	113 20 38·50

Hebe (6).

Mean Solar Time of Observation.	R.A. from Observation.	N.P.D. from Observation.
h m s	h m s	o ′ ″
1861, April 4 9 58 48·6	10 51 34·90	70 48 44·13
5 9 54 22·9	10 51 5·02	70 44 56·99
8 9 41 13·0	10 49 42·62	70 35 39·15
11 9 28 15·2	10 48 32·40	70 28 8·38
16 9 7 8·0	10 47 4·43	70 19 50·36
20 8 50 40·0	10 46 19·76	70 16 48·79
23 8 38 34·8	10 46 2·48	70 16 27·96
24 8 34 34·5	10 45 58·09	70 16 41·50

Parthenope (11).

Mean Solar Time of Observation.	R.A. from Observation.	N.P.D. from Observation.
h m s	h m s	o ′ ″
1861, April 4 10 20 33·6	11 13 23·50	79 1 13·75
5 10 15 59·9	11 12 45·57	78 57 20·20
16 9 27 14·5	11 7 14·27	78 28 8·32
20 9 10 14·4	11 5 57·63	78 23 8·99
23 8 57 45·1	11 5 15·93	78 21 28·30
24 8 53 38·6	11 5 5·31	78 21 11·64

Melpomene (18).

Mean Solar Time of Observation.	R.A. from Observation.	N.P.D. from Observation.
h m s	h m s	o ′ ″
1861, April 4 7 39 22·7	8 31 46·12	71 46 52·15

Leda (38).

Mean Solar Time of Observation.	R.A. from Observation.	N.P.D. from Observation.
h m s	h m s	o ′ ″
1861, April 8 10 46 24·4	11 55 4·79	100 55 37·03

Lætitia (39).

Mean Solar Time of Observation.	R.A. from Observation.	N.P.D. from Observation.
h m s	h m s	o ′ ″
1861, April 10 11 42 34·1	12 59 16·75	86 6 29·78
16 11 14 37·4	12 54 54·80	85 29 21·28

Eugenia (45).

Mean Solar Time of Observation.	R.A. from Observation.	N.P.D. from Observation.
	h m s	h m s	° ′ ″
1861, April 5	11 39 36·0	12 36 35·39	86 0 32·30
25	10 7 56·5	12 23 31·91	84 18 37·54
27	9 59 8·6	12 22 35·74	84 12 32·81

All the observations of N.P.D. are corrected for refraction and parallax.

The observations of *Angelina* (61), printed in the *Monthly Notice* for April, were made, 1861, March 21 and 22, and not, as there stated, March 15 and 22.

No occultations of Stars by the Moon were observed.

Phenomena of Jupiter's Satellites.

Day of Observation.	Satellite.	Phenomenon.	Mean Solar Time.	Observer.
1861.			h m s	
April 5	IV.	Ingress, first cont.	11 7 58·4	J. C.
5	IV.	,, bisection	11 12 27·7	J. C.
5	IV.	,, last cont.	11 17 56·8	J. C.
5	IV.	,, first cont.	11 8 50·7	N.
5	IV.	,, bisection	11 12 35·1	N.
5	IV.	,, last cont.	11 16 34·4	N.
8	II.	Egress, last cont.	7 47 6·6	A. D.
16	III.	Ecl. reappearance	7 17 45·2	C.
23	III.	Ecl. reappearance (*a*)	11 16 39·0	E.

(*a*) The satellite was thought to have reappeared a few seconds before it was seen.

The initials E., C., J. C., A. D., and N., are those of Messrs. Ellis, Criswick, Carpenter, Davis, and Newcomb.

Mr. Carrington's Chronograph.

Mr. Carrington exhibited at the evening Meeting an instrument for the registration of time-signals on a fillet of paper, the parts of which were put in motion that their performance might be inspected in working order. He commenced his explanation by acknowledging the assistance he had received in carrying out his ideas from Mr. C. V. Walker, Telegraph Engineer to the South Eastern Railway Company, who permitted the works to be executed at Tunbridge by the skilled workmen at the clock-factory under his direction.

In devising a modified form of Chronograph his object was twofold; 1st, to supply a want felt last summer at Redhill during a period of great solar activity, of the power of recording many more signals in a given time than could be done by the ear, eye, and pencil; 2d, to endeavour to reduce the cost of such an instrument so considerably as to place it within the reach of all observers; for in his intercourse with private astronomers he had frequently become aware of the difficulty found by them in making observations of position where it was required to count and register differences of time with a half-second chronometer.

The parts of the instrument, of which full-size plans will be deposited with the Society, were mainly three; 1st, the reel carrying the fillet; 2dly, the machine for driving and stamping; and 3dly, a sustained pendulum, by which at every vibration a current was allowed to pass from a battery of three cells, and the time-pen of (2) made to register a time scale dot. The reel can require no particular description, but it may be stated that the fillet wound on it was in size and quality similar to that used for the London District Telegraphs, and may readily be procured at an extremely low price in any length and quantity. The pendulum was of a length beating $\frac{6}{10}$ seconds, (in the instrument exhibited) and was accompanied by only so much of the usual clock-train as was necessary for keeping up its vibrations and enabling it to do the work required, of making slight metallic contacts. For this purpose it was crooked at about one-fourth of its length from the point of suspension, and a steel point introduced directed upwards, which at every vibration in passing the lowest point touched a point on the other side of a small doubly inclined plane, placed beneath a horizontal flexible spring. By the momentary contact so made, the duration and delicacy of which was regulable by a screw, two ends of a wire were placed in metallic contact, and a current allowed to pass to the machine (2).

This portion (2) consisted of a train of wheels for driving and regulating the rotation of a narrow drum, over which passed the fillet, which was drawn along at a rate liable to very small variation from under an inking desk, through the bottom of which worked three small platina plungers or wire pens, dropped by the passage of galvanic currents through corresponding pairs of electro-magnets. The regulation of the rate of the driving train was effected by two small centrifugal spring pieces, attached to the circumference of a fly forming the last wheel of the train, and the friction of which against two opposed surfaces admitting of adjustment established and maintained an evenness of rate amply sufficient for the object in view. The arrangement of the inking apparatus is due to Prof. Wheatstone, from whom was borrowed the ingenious idea of drilling holes through the bottom of a metallic disk too

small to admit of the escape of a drop, and through which the plungers or pens descend freely, with their tips constantly moistened by the capillary action of the small holes in which they remain while at rest.

The descent of the middle pen was regulated by the pendulum, and recorded on the fillet a series of centre dots at distances indicating on the scale intervals of time of six-tenths of a second. The other two, which may be termed the A and B pens, are under the control of the observer, who holds in his hand a contact maker, with which either one or the other pen is made to descend instantaneously and record a dot. In Mr. Carrington's method of observing the positions of solar spots, the interval of passage of the Sun's diameter would be represented on the fillet by a length of about $10\frac{1}{2}$ feet, divided into equal intervals, and on one side by the A pen would be recorded the contacts of limbs and spots with pen A, and on the other those of pen B, the unit of measurement employed being of no moment whatever; and it is evident that, wherever two co-ordinates can be observed instantaneously by this or analogous methods, the new Chronograph will be found an aid to the observer. Its especial use is, however, in cases where it is necessary to record with great rapidity, or in the absence of all light, as when a faint object is present in an equatoreal; other previously devised instruments being more suitable for meridional observation.

The machinery and weights of the instrument exhibited cost less than 12*l.*, a part of which was incurred by alterations necessary in a first trial, and with table, battery, and appurtenances, the whole did not exceed 13*l.* The essential parts of the common clock may be purchased in Clerkenwell at prices far less than would commonly be believed till known; and if a clever workman disposed to employ his evenings after usual hours can be met with, experiments similar to those from which resulted the above machine may be tried without very alarming or deterring expense.

Observations and Elements of Comet I., 1861.

(*Extract of a Letter from Mr. Bond to Mr. Carrington.*)

The comet discovered by Mr. A. E. Thatcher, of New York, on April 4th, has been observed here as follows:—

Comet I, 1861.

1861.	Camb. M.S.T. h m s	R.A. h m s	Decl. ° ′ ″
April 10	11 34 42	17 7 42·60	+59 28 12·8
11	9 27 6	17 2 26·69	60 9 0·2
14	9 1 27	16 40 14·35	62 30 7·1
18	14 21 33	15 49 15·55	65 52 42·9

On account of an error in the place of the comparison-star, the declination of the comet, April 9th, was erroneously reported to the *Astronomische Nachrichten*, and to the Bulletins of the Paris Observatory, as

$$+59\ 30\ 13{\cdot}8$$

instead of

$$+59\ 28\ 12{\cdot}8$$

Mr. Safford has computed the following elements of the Comet:—

T 1861, June 4·004, Washington M.T.

Motion direct.

$\pi - \Omega = \omega$	213 15·30
Ω	29 15·13
i	81 14 23
Log q	9·96544.

Harvard Observatory, April 8, 1860.

Observations of the same Comet. By Sandford Gorton, Esq.

Mr. Gaunt and I observed the Comet at this place on the 4th of May, at 11 P.M. It was visible to the naked eye, appearing like an indistinct star of the 2d or 3d magnitude. It was sufficiently bright to be well seen in the field under an illumination which extinguished stars apparently of the 6th magnitude. In the dark field a tail was readily to be traced, extending in the S. F. quadrant to a distance of about a degree, as far as I could judge. Its rate of progress in declination was so rapid that we watched it approach and pass a star during the hour we were observing.

On the 6th and 8th I again saw it, but with difficulty, owing to the mist.

Last night (the 9th) was also misty, and the comet could scarcely be seen without the telescope.

The following are the approximate positions shown by my

Equatoreal, which, of course, are open to correction by more powerful instruments: —

	G.M.T.	R.A.	Decl.
	h m	h m s	o ′
May 4	11 0	9 51 10	+45 5
6	12 30	9 27 55	37 10
9	9 35	9 3 35	26 18
„	11 28	9 3 10	25 59½

Telescope, 4 feet focal length; aperture, $3\frac{3}{8}$.

Observatory, Downs Road, Clapton,
May 10, 1861.

Discovery of Minor Planets (66), (67), (68) *and* (69).

The discoveries of the first three are announced in the *Astronomische Nachrichten*, No. 1308, and Circular of 6 May, 1861, and that of the last in Le Verrier's *Bulletin* of the 13th May, which contains also some later observations of (67) and (68).

Minor Planet (66). Discovered by Mr. H. P. Tuttle at the Observatory of Harvard College, Cambridge, U.S., on the morning of April 10th; magnitude 13. The following positions were obtained from comparisons made by Mr. Bond with a star of the 7–8 mag. W. 1011, occurring also in Santini's Catalogue and the Harvard zones 6 and 7, No. 76.

1861, April 9, $14^h\ 36^m\ 23^s$ Camb. M.T.

R.A.	Par. × Δ.	Decl.	Par. × Δ.
$11^h\ 59^m\ 45^s{\cdot}83$	$+0^s{\cdot}358$	$+0°\ 9'\ 12''{\cdot}7$	$+5''{\cdot}74$
	Daily Motion -43^s	$0'$.	

Minor Planet (67), *Leto*. Discovered by Dr. Luther at the Bilk Observatory, at $12\frac{1}{2}$ on the night of the 29th of April, in R.A. $14^h\ 9^m\ 35^s$, Decl. $-11°\ 6'\ 3''$; magnitude 11. The following observation was made,—

	Bilk M.T.	R.A.	Decl.	Comps.
1861, April 29	$13^h\ 21^m\ 2^s{\cdot}0$	$14^h\ 9^m\ 32^s{\cdot}73$	$-11°\ 6'\ 15''{\cdot}1$	8
	Daily Motion -54^s		$+2'{\cdot}2$	

The star of comparison being taken from Rumker's Catalogue:

	Mag.	App. Position.		Mean Position, 1861.	
April 29	6	$214°\ 0'\ 6''{\cdot}1$	$-11°\ 4'\ 53''{\cdot}0$	$213°\ 59'\ 16''{\cdot}6$	$-11°\ 4'\ 34''{\cdot}2$

The name was selected by Prof. Argelander, Dr. Krüger, and M. Tiele, at Bonn.

The following later observations by the discoverer are given in Le Verrier's *Bulletin*:—

	Bilk M.T. h m s	R.A. h m s	Decl. ° ′ ″	
April 30	10 52 17·5	14 8 44·76	−11 4 5·2	8 comp.
May 7	10 42 19·7	14 2 35·91	−10 48 1·4	10 comp.

Minor Planet (68). Discovered by M. Schiaparelli at the Royal Observatory of Milan, April 29; magnitude 11.

1861.	Milan M.T. h m s	App. R.A. h m s	App. Decl. ° ′ ″
April 29	11 26 5	10 22 13·83	+7 37 49·9
30	9 16 27	10 22 36·74	+7 38 47·2
May 1	8 53 56	10 23 3·19	+7 39 49·8
2	8 56 36	10 23 30·72	+7 40 36·9
3	9 1 30	10 24 0·02	+7 41 20·7
7	9 3 7	10 26 6·91	+7 42 36·2
8	9 5 56	10 26 41·46	+7 42 36·1
9	8 57 1	10 27 16·66	+7 42 23·4

where the observations on and after the 2d of May are taken from Le Verrier's *Bulletin*.

The planet at the time of its discovery was distant only 9′ from *Ausonia* (68), and it was at first taken for that planet.

Minor Planet (69), *Panopea*. Discovered by M. Goldschmidt at Fontenay aux Roses, near Paris, on the 5th of May, mag. 10–11. The following observations have been obtained:

1861.	Paris M.T. h m	R.A. h m s	Decl. ° ′ ″	
May 5	10	14 43 43	−14 20	(*a*)
10	10 44	14 38 30	−14 21 54	(*a*)
11	11 45	14 37 25	−14 23	(*a*)
14	10 10	14 34 16·91	,,	(*a*)
14	10 45	14 34 15·30	−14 25 36	(*b*)
15	10 57	14 33 14·55	,,	(*b*)
15	11 29	,,	−14 26 19	(*b*)
16	9 55	14 32 14·8	−14 29 29	

		h m s	° ′ ″
(*a*). Star of Comparison (1800)	Berlin Cat. R.A.	14 34 52	Dec.−14 8 3
Reduced for 10 May	App. R.A.	14 38 15	Dec.−14 24 26
(*b*). Star of Comparison (1800)	Berlin Cat. R.A.	14 29 56	Dec.−14 27 2
Reduced for 14 May	App. R.A.	14 33 19·15	Dec.−14 43 36

The observations of the 14th, 15th, and 16th of May are taken from a letter dated $\frac{16}{17}$ May, 1861, to Mr. Carrington. The name *Panopea* was selected by Mr. Main.

Since the above was in type, the following communication has been received from Mr. Pogson:—

Discovery of a New Planet, "Asia."

This planet was found, like each of my previous ones, by means of my own manuscript charts; not by mere gleaning in the celestial fields prepared by other astronomers; a circumstance which enables me to assume with reasonable probability that I shall not have been preceded elsewhere. As it is the first discovery yet made in this quarter of the world, I have selected the name "*Asia*," who, as one of the Oceanides, has, I conceive, as good a right to a place in the heavens as *Europa*, *Doris*, or several others of her sisterhood. The planet is between the 11th and 12th magnitudes.

The following observations have been taken by the Boguslawski method, using only one thick bar and two comparison stars, there being no dark field micrometer attached to the telescope. I believe them to be fully equal to any I could have made of so faint an object, had the most refined instrumental means been at hand.

1861.	Madras M.T.	App. R.A.	App. N.P.D.	Log. of Par. × Δ. R.A.	Log. of Par. × Δ. N.P.D.	Comp. Stars.
		h m s	h m s			
April 17	12 53 40	15 51 14·76	...	−9·265	...	*b c*
17	14 7 37	15 51 13·56	106 6 22·9	+6·704	−0·620	*b c*
18	11 50 39	15 50 50·72	106 1 12·7	−9·501	−0·578	*b c*
19	13 49 27	15 50 20·72	105 55 7·0	−8·368	−0·617	*b c*
20	11 46 44	15 49 53·93	105 49 50·1	−9·686	−0·579	*b c*
20	13 20 12	15 49 51·84	105 49 26·6	−8·934	−0·614	*b c*
21	11 59 5	15 49 22·97	105 43 55·3	−9·431	−0·587	*a b*

The second observation, on April 20, was taken and reduced by my fourth native assistant, Raganootha Chary, who readily comprehends and most willingly executes whatever I may recommend to his notice.

The adopted mean places of the comparison stars were these:—

		Mean R.A. 1861.	Mean N.P.D. 1861.
		h m s	° ′ ″
a	A.Z. 297·58 = 28997 Lalande	15 49 13·23	105 37 30·4
b	A.Z. 205·62	15 51 20·78	105 49 11·5
c	2026 Mädler's Bradley	15 52 31·93	106 7 14·7

The right ascension of 28997, being 6 seconds of time too great, was rejected, and Argelander's alone employed.

Madras Observatory, April 27, 1861.

The announcement, in the last Annual Report of the Council, of the death of Sir W. Dennison (p. 98), was erroneous. The Astronomer Royal has received a letter from him, dated April 8, then alive and well, and governing at Madras.

ERRATA.

Page 173, line 5 from top, *for* Lieut. Cuspendale, *read* Lieut. Carpendale.
— 178, — 20 — *for* L. H. Casella, *read* L. P. Casella.

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